sible from quantitative tests of the ferments elaborated by the human stomach, and yet this does not preclude the possibility of more reliable information of the pancreatic gland being obtained by this method of testing. It will remain to be demonstrated whether moderate pathological changes in the tissue of the gland will evidence itself by variations in the titer of the enzymes of the external secretion.

The study of a vast clinical material, with a uniform method of collecting and testing the duodenal contents in these cases, will be necessary to establish the further value of this method.

Since writing this article for publication, the author has noted the appearances in the literature of the experiences of Frank[20] with this same method. Frank succeeded in obtaining duodenal contents in 60 per cent. of the persons he attempted. The cases were chosen at random and suffered no pancreatic disease. The duodenal contents in all these instances showed active alkali-protease where tested for. The other ferments were not investigated. The inability of Frank to obtain the duodenal material desired in 40 per cent. of his essays is probably due to too short a time being allowed for the metallic capsule to enter the duodenum. This is obviated in my series of cases, by passing the pump in the evening and allowing the entire night to elapse before aspirating the desired material. Even then, more than one attempt is sometimes required before success is attained. The procedure is a mild one, and only exceptionally objectionable to the patient.

The sincerest thanks of the author are offered to the physicians and surgeons of the attending staff of Mount Sinai Hospital for the privileges of studying clinical material in their wards; to Dr. Samuel Bookman, for kind suggestions and hearty coöperation. and to the House Staff of the Hospital (more particularly Dr. Mahler) for general assistance throughout the course of this work,

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A STUDY OF EMPYEMA, WITH SPECIAL REFERENCE TO THE FEASIBILITY AND IMPORTANCE OF DEPENDENT DRAINAGE.[1]

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The large number of operations which have been done in recent years has added much to our knowledge of the pathological changes which have taken place and the mechanical conditions which have arisen in connection with the various disease organs or tissues on account of which the operations have been performed. Our opportunities for the study of a pathological condition are much improved when during the operation it becomes necessary to remove the diseased organ or tissue, as in appendectomies, gastrectomies for ulcers or carcinoma, or in operations for the removal of other tumors. Even when nothing is removed a free exposure of the affected part is often obtained, so that practical observations can be made from sight and touch. Yet from the large number of operations which have been done for empyema we have learned little in this way. The opening made in the chest wall is too small for inspection of the diseased parts within, in the presence of the escaping pus, and the finger is too short for palpation. Our efforts, of necessity, have been confined chiefly to bacteriological examinations of the pus evacuated and to a study of the relation of the pus collection to the preceding infectious condition of the lung, as pneumonia or phthisis. Robinson[2] says that the bacteriology is of interest in prognosis, but of no significance as regards treatment. All cases should be recognized promptly and drained freely, reëxpansion of the lung being the main purpose from the start. Most surgeons will probably agree with these statements.

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[20] Archiv f. Verdauungs-Krankheiten, 1912, xviii, 121.

[1] Read before the College of Physicians of Philadelphia, November 6, 1912.

In a previous paper[3] on empyema I employed an illustration of a formalin-hardened cadaver specimen, from the department of applied anatomy of the University of Pennsylvania, of an empyema from which the pus had not been evacuated during life. The possession of this specimen is the result of an accident, it having been selected for injection with formalin as one in which the normal relations and conditions of the abdominal and thoracic organs should be found, and I used it for the first time to illustrate how easily a large empyema could be overlooked on inspection. I have come to the conclusion that it was worthy of a more careful study and that it might yield valuable practical information concerning empyema in general. When making a study of conditions in the dead body we usually obtain our material from the dissecting or postmortem room. This kind of a specimen could hardly be obtained from either. It must be specially prepared, and one must know that the unopened empyema is in a body before he prepares it, unless, as in this case, he happens to find it by accident after he has injected the body with formalin. The number of empyemas that find their way into the postmortem room unrecognized and unopened is probably very small, and those that do are usually so mutilated before the empyema is recognized that the preparation of a formalin specimen of this kind would be impossible.

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[2] Boston Med. and Surg. Jour., 1910, clxiii, 501.

[3] Internat. Clinics, 1906, 165; iii, 150.

The first incision and manipulations necessary to expose the empyema would render the injection of the formalin ineffective, and would distort the relations of the soft structures to each other. In the dissecting room the conditions would be similar or worse for the preservation of a similar specimen. If an opening had been made during life, such changes would have taken place that would have rendered the specimen less valuable, because we are most interested clinically in the empyema before the pus has been evacuated. Fig. 1 shows that there existed here the large common

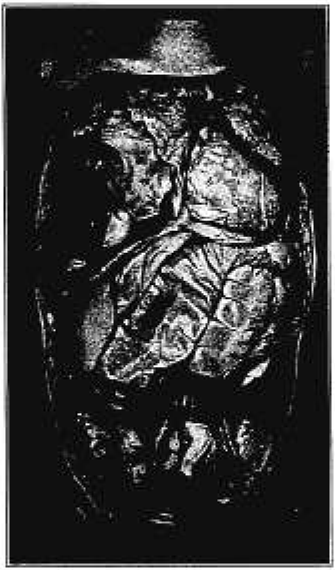

FIG. 1.—Formalin hardened cadaver specimen of an empyema which has been completely circumscribed by firm adhesions above between the lung and chest wall. A small portion of the lung, narrower than appears in the illustration, remained adherent to the diaphragm. The costophrenic sinus is much wider than normal from the pressure of the pus, while on the opposite side it is almost obliterated. The heart pushed to the left looks larger than it actually is because abnormally uncovered by the left lung which is crowded posteriorly and to the left. The placing of the drainage opening at the bottom of the normal pleural cavity (see Fig. 2) would have been easy and safe in this case, as it proved to be in the three cases in which it was so placed. The large intestine is much distended and the liver distorted and depressed by the pressure of the pus.

and typical empyema, that giving marked and superficial dulness extending from the bottom of the pleural cavity a variable distance upward and merging below on the right side with the liver dulness. The displacement of the heart and liver are also typical.

A bacteriological examination of the pus debris remaining in the specimen was made by Dr. Rivas, of the University of Pennsylvania. He found in it leukocytes, lymphocytes, two kinds of bacilli, and a diplococcus. One of the bacilli was acid-fast, and suggested the tubercle bacillus. This was confirmed by a longitudinal section of the affected lung. The specimen had been lying in a strong formalin solution for about eight years, so that the pus debris from which Dr. Rivas made his examination had undergone such change as not to permit an exact bacteriological report. He concluded that the pus had been the result of a mixed infection. The most striking and important feature in connection with the specimen, in my opinion, is that the empyemic cavity, although a large one, is distinctly and firmly circumscribed below by the junction of the diaphragm and chest wall and above by adhesions between the lung and chest wall, so intimate and continuous that the line of cleavage between the two cannot be seen. I have seen a formalin preparation of a tuberculous empyema in which there were no adhesions between the two pleural layers, the lung lying completely collapsed against the spine. The probability is that in the latter there had developed a communication between a bronchus and the pleural cavity, resulting in a pneumothorax in the presence of a slight tendency toward adhesion formation. In my specimen there could be found no evidence of such a bronchial communication after a careful search of all surfaces presenting on the empyema, which was aided by a removal of a longitudinal section of the lung, about 3 inches wide, and extending the whole length of the lung. The firm and extensive adhesions sharply circumscribing the empyemic cavity were probably due to absence of a bronchial communication, and the fact that there was added to the tuberculous a pyogenic infection; the latter having a greater tendency toward adhesion formation than the former. This does not mean that tuberculous infection cannot produce the condition exhibited by this specimen. There is much vagueness in the literature concerning the existence of and the part played by adhesions in empyema. Many writers ignore their existence; some refer to bands of adhesions; while others seem to think their existence is largely a matter of chance. If they developed extensively in the presence of a mixed tuberculous and pyogenic infection, as in this case, I believe they are almost certain to occur in the acute pyogenic infections, including the pneumococcic, in which pneumothorax is rare. Indeed, the burden of proof should not be upon him who says that such adhesion formation is the rule, but upon him who says that it is not.

The empyema in this specimen extended from the bottom of the normal pleural cavity upward, anteriorly at one point as high as the second rib and posteriorly in a rather broad channel as high as the apex. It was one continuous cavity and no bands of adhesions crossed it. It was thoroughly walled off on all sides: above by close and firm adhesion between the lung and chest wall, and below by the union of the diaphragm and chest wall. I have based my study of empyema chiefly upon the character of the adhesion formation in this specimen, and upon the assumption that it is the rule in acute empyema. Many of the accepted teachings in connection with empyema, according to my judgment, have either taken no account of this feature or have not given it sufficient recognition. I have drawn some inferences from my study that I look upon more as suggestions than conclusions. The main definite conclusion I would draw is that dependent drainage in empyema, which calls for an opening as low as the eleventh rib or to the top of the twelfth rib in most cases, is not only feasible but comparatively easy and safe.

This massive type of empyema is frequently referred to as the unencysted or general, which implies that the pus is free to flow into all parts of the affected pleural cavity. The specimen strongly contradicts this conception, and shows, in my opinion, that practically all acute empyemas are encysted and localized by surrounding more or less firm adhesions, as in an appendicular or other abdominal abscess, or the small so-called localized empyema. The latter is localized, but probably no more so than the large one.

Morison[4] says that the collecting effusion is first observed in the region of the fifth interspace, that is, diagonally farthest from the fixed point of the lung at its root, and that the reëxpanding lung last touches the chest wall in the same region. For this reason he makes this the point of election for the drainage opening. According to my experience most empyemas extend from the bottom of the pleural cavity, as in this specimen, a variable distance upward. I believe that the fluid begins to collect not about the fifth rib, but at the bottom of the normal cavity. Donaldson[5] says that "the fluid products in pleurisy gravitate by their weight to the lowest portion of the cavity of the pleura and then gradually rise." The last part of the lung to reëxpand is probably that about the drainage opening, at whatever level it may be, where the external atmospheric pressure acts longest and to the best advantage. Considerations based upon this specimen suggest the following conception as to the conditions developing in and about an empyema. Most pneumonias affect the base of the lung, therefore the resulting pleural effusion should begin at the base of the pleural cavity. But let us suppose that the infection involves a higher portion of the lung and reaches the pleura on the corresponding portion of the external surface of the lung. If adhesions develop between the visceral and parietal pleuræ, here, there can be no empyma, because there is no space in which the fluid can collect. If no adhesions develop the excess of fluid which results from the pleurisy falls immediately to the bottom of the pleural cavity and prevents adhesions between the surfaces over which it continues to fall. It should collect first in the costophrenic sinus, pushing the lung here away from the chest wall and diaphragm and the latter two from each other, as in the specimen. I would again agree with Robinson when he says that he is "not in sympathy with Fowler, who says that adhesions may occur in the costophrenic angle, raising the level of the bottom of the cavity so that the drainage need not be at the lowest point." Such adhesions might develop after a drainage opening had been made, but are not likely before. The accumulating fluid pushes the serous surfaces apart, but sooner or later where they are in contact above the pus collection and around the whole lung the approximated surfaces develop adhesions, weak at first but gradually growing firmer. In this way the pus becomes walled off all around by adhesions between the lung and chest wall, and probably some part of the diaphragm. This walling off is much more likely than with the average pus collection in the abdominal cavity, because in the pleural cavity the pus is less likely, from the nature of the cavity and the usual position of the patient, to move about. For the same reason a pelvic infection is less likely to give rise to a general peritonitis than one in the appendix or gall-bladder region. The cadaver specimen shows clearly that such a walling off occurred in this case, and that it usually occurs in empyema is strongly indicated by the fact that when a patient is changed from the sitting to the recumbent position there is little or no variation in the upper line of dulness. Movable dulness is probably rare in empyema, except perhaps in the early stages, before the adhesions have become strong enough to withstand the pressure of the pus under the influence of gravity. Donaldson says: "Once formed, these effusions (of pleurisy) are but slightly movable and but little displaced by the varying positions of the patients, unless the quantity be very great and no adhesions or bands have been made." He also says, "The serous transudations of hydrothorax always occupy the most dependent portion of the cavity." In other words, the fluid in the latter moves about under the influence of gravity. In an empyema the weight of the pus might cause a slight change in its position by pressure against the more or less soft lung. We know that the upper line of dulness in the sitting position is not straight but curved, the curve varying more or less, and that it does not change materially when the patient is placed in the recumbent position. The varying curve of this line is probably dependent upon the position occupied by the patient during the development of the limiting adhesions. The absence of movable dulness as determined by percussion before and after a change in the position of the patient should be a sufficient guarantee that the pus has become circumscribed by adhesions in any given case.

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[4] Trans. Med. Chir. Soc., Edinburgh, 1907 to 1908, vol. xxvii.

[5] Pepper's System of Medicine, iii, 487.

The adhesions probably developed early and became stronger as the quantity of pus, and therefore its upward pressure increased, so that they held the adherent surfaces of the lung to the chest wall while the under surface of the lung removed from the chest wall was being pushed upward, the pus therefore reaching its highest level a variable distance from the chest wall. Above this level, especially when the pus collection is large, the percussion note is often hypertympanitic—Skoda's resonance—particularly in the first and second interspaces anteriorly. In the formalin specimen the pus at one point reached as high as the second rib, so that in large collections the first and second ribs or interspaces anteriorly cover about all of the lung above the pus that comes as close to the skin surface. Posteriorly and above the first rib anteriorly it is covered by a much thicker layer of muscles and other tissues. The inference to be drawn is that the lung is more tympanitic anteriorly in the first and second interspaces because it is nearest to the surface here. Skoda's resonance is explained by a retraction and relaxation of the lung from its elasticity and the upward pressure of the pus. This implies that the lung is being floated upward by the pus causing it to become relaxed. It has seemed to me that retracted and relaxed lung must be more or less functionless according to the degree of collapse, resulting from the relaxation. If its air cells are full of air and functionating it can hardly be collapsed. The support which the lung obtains from its firm attachment to the chest wall in its whole circumference must aid it in resisting the upward pressure of the pus and in keeping its air channels open for respiration. The lung is not floating in the ordinary sense on the fluid pus, and therefore largely collapsed and functionless, but is probably trying to maintain its function with the aid of the extensive firm adhesions, the atmospheric pressure exerted through the trachea, and with the aid of an increase in the capacity of the thorax produced by the auxiliary muscles of respiration. The portion of the lung tissue caught between this air pressure above and the pus pressure below is probably compressed and condensed, not relaxed. In the normal lung conditions the tidal air is only about one-third of the air contained in the lung. Necessity may now increase the proportion of the tidal air in the functionating portion of the lung, so that the hypertympany may be the result of overdistended, not relaxed lung. Auer and Meltzer[6] say that the actual necessity of respiratory function for the mere maintenance of life amounts only to a small fraction of the normal respiration, and that the extent of the changes of gases occurring in normal respiration with a closed thoracic cavity exceeds greatly the need for the maintenance of life, since normal respiration is provided with an abundance of factors of safety. Necessity demands in an empyema that any still functionating portion of the lung shall work to its full capacity. It is generally agreed that the lung on the sound side is doing compensatory work, why not any sound lung on the affected side? That it probably does so is strongly indicated by the fact that a patient can live with a large empyema on each side, and the fact that he can live under these circumstances, indicates that the pressure of the large collection of pus on each lung is being largely offset by the extensive firm adhesions in the whole circumference of each lung. These began to develop early and resisted with increasing firmness the increasing pressure.

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[6] Jour. Exper. Med., 1911, xiv, 569.

If a considerable portion of the lung is so functionating then it follows that this portion is occupying about its normal proportion of the thoracic cavity, and the portion which formerly occupied the space now represented by the empyemic cavity must be more or less compressed and condensed below the functionating portion. The adhesions were developed in the early stages between surfaces about in their normal relations to each other, and they probably continued to hold these surfaces together against the pressure developing later from the accumulating pus. This means, in my opinion, that the adhesions will not seriously hinder the reëxpansion of the lung after the pus has been evacuated, and that the cavity is to be filled by reëxpansion of that portion of the lung which presents upon or projects into the cavity. The adherent surface of the lung is about where it should be when the lung is fully expanded, and therefore the adhesions should not be broken up to favor reëxpansion of the lung.

Elsberg[7] reported some interesting facts concerning pneumothorax, observed in experimental work on dogs. Many of the dogs either died suddenly as soon as an opening was made into the pleural cavity, or a violent expiratory dyspnea ensued, soon followed by rupture of the mediastinal septum, double pneumothorax, and death. While most of the dogs stood well, a small opening in the chest wall, sudden heart stoppage or dyspnea, and death followed in some instances. The larger the opening, however, the more likely is the occurrence of serious interference with the respiration. In almost all the animals in which the size of the opening approached or exceeded that of the diameter of the trachea, when the dog was lying on its back, dyspnea and death followed. It made no difference in what part of the chest wall the opening was made. The cause of the rapid death seems to be the development of the double pneumothorax. If a dog will die of a total double pneumothorax a man should. But it is now known that a double empyema may be opened on both sides at the same operation and the patient live. Hellin,[8] after a study of 113 cases collected from the literature and 1 of his own, makes some very interesting statements in this connection. He says: "The question of a double empyema is closely related to that of a double pneumothorax. *A priori,* one would expect that a simultaneous opening of both pleural cavities would prove fatal. At first it was considered best to open the second pleural cavity after the first had been closed. (An interval of one hundred and fifty days was allowed to elapse in one case.) But compelled because of the severity of the constitutional condition, it was gradually found that the interval between the opening of the two cavities could be shortened until both were opened at the same operation. The skeptic can convince himself that the classical theory born of a fear of a double pneumothorax is unfounded, since the patients do not cease to breathe in spite of the two opened pleural cavities." Hellin in his case found that the cyanosis occurring during anesthesia disappeared on the opening of the pleural cavities. In experiments on dogs he noted that some of the animals survived even after the collapse of both lungs if the opening in the first cavity was closed. Auer and Meltzer showed that while from the opening of the pleural cavity in the dog, collapse of the lungs, dyspnea, and death occur, if the opening were closed after the collapse of the lungs had occurred, the dog would continue to live. Only an open pneumothorax causes dyspnea. When the cavity was closed, even though the lungs have recently collapsed, an inspiration will cause some distention of the lungs and an inspiration of air into them. An expiration will cause a compression of the lungs and a removal of the carbon dioxide. Hellin[9] inferred from his studies that a total double pneumothorax was not necessarily fatal, but that, as in caissons, it is chiefly in the suddenness of the change of pressure that the danger lies. But he assumed also that simultaneous opening on both sides of a double empyema gave rise to a total pneumothorax on both sides. Fabrikant[10] asks if we may not hope that under these circumstances pleural adhesions will prevent collapse of both lungs. The formalin cadaver specimen gives an affirmative answer to this question. It is possible that the adhesions in the early stages may break down at some point and admit air to any open part of the pleural cavity above; but this would probably be very rare, if it occurred at all. The empyema specimen which represents probably the great majority of this massive type shows clearly why a patient can live after the simultaneous opening of a double empyema on both sides. The air is admitted not into the whole pleural cavity of each side, but into only the strongly walled off pus cavities, which are now extrapleural in the sense that an appendiceal abscess becomes extraperitoneal. The atmospheric pressure can now exert its effect only upon the surface of the lung presenting on the empyema which is buttressed against a threatening collapse by the strong adhesions which before the opening was made protected it against the severe pus pressure. The atmospheric pressure is always the same, but the pus pressure will probably vary with the quantity of pus present, so that the immediate effect of the drainage opening on the lung will probably depend upon the difference in the two pressures one way or the other. It is my impression that I have seen patients breathe better after the operation when they are resting quietly in bed, and that I have seen cases in which the breathing was not as good.

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[7] New York Med. Rec., 1908, lxxiii, 846.

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[8] Berlin. klin. Woch., 1905, xlii, 1415.

[9] Archiv f. Klin., 1907, lxxxii, 866.

[10] Deutsch. Zeitschr. f. Chir., 1911, cviii, 584.

The fear is sometimes expressed that the rapid evacuation of the pus following the usual opening made by the resection of a small portion of a rib will be accompanied by a dangerous change of pressure on the surrounding displaced organs, especially the heart. Hellin feared this and advised that all empyemas, unilateral as well as bilateral, be aspirated immediately before operation or one or two days before, in order that a too sudden change of pressure may not take place. I have seen a fairly large number of empyemas opened, but I have never seen such a danger threaten, and I believe that it is very rare. With each outflow of pus from the opening on expiration there immediately follows an inrush of air on inspiration to take the place of the pus evacuated, until when the pus is all evacuated its place has been taken by air at a pressure of about 15 pounds to the square inch. There is therefore probably no great change of pressure, and certainly not a sudden one. The ominous loud noise made by the air rushing in through the opening with each inspiration is in reality an indication not of danger, but of safety. As already stated, Hellin observed in his case of double empyema that the cyanosis occurring during narcosis, disappeared after the empyemas had been opened on both sides.

I have operated upon three and possibly four of the so-called localized or encysted empyemas. Since I believe that the usual large variety is in practically all cases circumscribed by adhesions, I believe that these names do not properly distinguish the small ones. The status of these cases has not yet been decided. I would suggest that they are practically all interlobar or between the diaphragm and under surface of the lung and that that is the reason for their small size, the pus becoming walled off by adhesions before it can get out of the fissure or the space between the diaphragm and under surface of the lung.

In connection with these small empyemas, Musser[11] emphasized the importance of firm and deep pressure in the intercostal spaces along the fissures and along the margins of the diaphragm or upper borders of the liver, to develop tenderness indicating the presence of small empyemas between the lobes of the lung or between the lung and diaphragm.

Murphy[12] says that many of the cases diagnosticated as abscesses of the lung are actually the result of empyemas communicating with a bronchus. Those diagnosticated as lung abscesses are very likely small and covered by more or less lung tissue, that is, they are interlobar. The pus breaks into the lung and ultimately finds its way into the air passages because it cannot well extend in any other direction. Depending upon the depth in the fissure at which it develops, the pus may or may not extend along the fissure and come to lie directly under the chest wall when a small area of absolute dulness could be detected. It may fail to do so because of its depth, when it will be covered by a layer of lung tissue, the dulness be relative, and air sounds be detected over it. The fissure is so oblique that it would be practically impossible to evacuate some deep collections by finding the fissure through an opening in the chest wall, and usually in such cases it is necessary to reach the pus by going through the lung tissue covering it, first shutting off the pleural cavity if necessary by suturing the lung to the chest wall in the circumference of the opening in the wall. The presence of sufficient adhesions here would render this unnecessary. When the pus collection is in the outer portion of the fissure directly under the chest wall the lung in the circumference of the empyema will be firmly adherent to the wall. In my 4 cases, I had 3 of the superficial variety and 1 of the deep. Small empyemas may develop between the base of the lung and the diaphragm, as already stated, but I have had no experience with this variety. It is said that these small empyemas frequently develop on the external surface of the lung between it and the chest wall. If they do it probably will be in an adherent portion enclosing a non-adherent area. The probability is, however, that such a condition is rare, and if a careful examination is made it is likely that in these cases the pus collection is close to some part of one of the main fissures. Robinson believes that most of these cases are peripheral abscesses of the lung. He refers to 2 cases which he saw at autopsy and 3 upon which he operated, in all of which the evidence as he interpreted it pointed to their having originated in abscesses of the lung. This evidence consisted in the fact that he found lung parenchyma devoid of pleura on the pulmonary side of the cavity. He expected to find the inner wall of the empyema made up of visceral pleura.

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[11] Jour. Amer. Med. Assoc., January 5, 1907, xlviii, 24.

[12] Ibid., 1898, xxxi, 281.

I believe with Robinson that the pus will not often break through the pleura into the lung substance in the usual large empyema, that between the parietal and visceral pleuræ. As already stated, I believe that an interlobar empyema remains small because the pus becomes circumscribed soon from the fact that it cannot easily spread itself out in the fissure. Gravity probably has little effect on it, and the movement of the apposed pleural surfaces normally is probably slight. As soon as it becomes walled off the pus can increase in quantity only at the expense of the lung which surrounds it. When it can no longer make room for itself by pushing the lung aside it will destroy it as it will destroy any other tissue which confines it, even bone. The pleura will probably first become necrotic and then the lung tissue and the process will continue until the pus finds an exit or kills the patient. Sometimes it will burrow externally through an interspace between the ribs. The lung is the weaker tissue, however, and therefore evacuation through the trachea, is the more common. We should not expect to find the pleura intact on the visceral side if the empyema has existed long enough to destroy it, and in many cases it probably has, by the time the empyema is opened, because this variety is usually the most difficult to detect.

The main purpose of any general study of empyema should be to improve our methods of treatment. In recent years we have had a number of valuable contributions looking toward this end. The main discussion seems to centre about the question of the method of drainage, and the consideration which has received most attention is that of the influence of the atmospheric pressure admitted through the drainage opening. Most cases get well sooner or later from drainage in the usual way, but in a considerable number the closure of the opening and cavity is much prolonged, or they may not close at all. Murphy[13] says that before the surgeon makes an opening into an empyema he should be reasonably certain that it will close later. He has discarded operation in all cases in which there is not an external opening or a communication with a bronchus. In other words, if air has not already gained entrance into the empyemic cavity through an external or an internal opening he will keep it out. He aspirates the pus and injects into the cavity a few drams or ounces of a 2 per cent. formaldehyde and glycerin solution, repeating the procedure at intervals of a few weeks as the effusion re-collects, until it has entirely disappeared. The fact that Murphy employs it in all cases, with the exceptions mentioned, attests its value and alone makes it a method which will be widely tested when it has been fully placed before the profession. As yet he has spoken of it only briefly in the discussion of papers by others. The formalin is said to render the cavity sterile and to favor the absorption of the exudate. Tennant[14] tried the method, but in one case it failed him and a resection of a rib was done. It is the ideal method for combating the ill effects of atmospheric pressure on the external surface of the lung, and if it comes into general use there will be fewer cases calling for the severe Estlander or Schede operations. But it has not yet received general approval, and the prevailing treatment is that with drainage.

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[13] Section on Surgery of the American Medical Association, 1909, p. 921.

Many devices and methods of obtaining drainage with the exclusion of air from the cavity have been offered, and recently von Eberts[15] and Robinson have added valuable contributions on this phase of the subject. Except for a brief attempt in one of my cases, which was soon discontinued, I have not as yet had any experience with these methods. It seems to me that before we can determine, with satisfaction, the relative value of suction or siphon methods of drainage we must first know approximately the limit of rapidity with which an empyemic cavity may be permitted to become obliterated. We are dealing with an abscess the walls of which are infected, and few surgeons will risk efforts at disinfection by irrigation. The rule is to permit the cleansing to be done by the natural processes after effective drainage has been instituted. In most cases in which drainage is employed in the usual way, without the use of suction, the cavity cleanses itself spontaneously and is obliterated by the expansion of the lung, sooner or later. Fraley[16] reported a study of 500 cases of pleurisy treated at the Pennsylvania Hospital. About one-fifth of them were empyemas. No case was cured in less than four weeks. The average was ninety days, in which column were found one-third of the cases. All but 6 were cured in four months or less, and these were severely complicated. The shortest duration of convalescence obtained by Robinson with his method of rib trephining and suction drainage was four weeks, although in the one fatal case, in which death occurred two weeks after operation, the lung was fully expanded as shown at autopsy. We might argue with some force, therefore, that about four weeks are necessary, under the most favorable conditions, for the disinfection necessary before the cavity and drainage opening can close permanently. But the conditions vary. The degree of firmness with which the lung has become fixed in its compressed condition will affect the rapidity of expansion. The character of the infection will affect the rapidity of spontaneous cleansing, as will the presence of necrotic tissue in the wall of the empyema. According to Schädler, quoted by Hellin, the average duration of a unilateral empyema was fourteen and one-half weeks, in children nine weeks. Hellin says that the death rate in 1335 cases of unilateral empyema was 22.4 per cent.

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[14] Jour. Amer. Med. Assoc., August 15, 1908, p. 572.

[15] Von Eberts and Hall, Montreal Med. Jour., June, 1910, 513; Annals of Surg., 1910, lii, 502; Ibid., 1911, liv, 59; Jour. Amer. Med. Assoc., 1912, lix, 264.

[16] AMER. JOUR. MED. SCI., May, 1907.

or 299 deaths. The mortality in the double empyemas was 0.1 per cent. Robinson evidently made a careful study of other methods of suction drainage than his own, and of them he says: "It is well known to those who have performed rib resection and introduced tubes protected by rubber collars, rubber dam, adhesive plaster, lanolin, zinc ointment, gutta percha, cement, and other agents that leakage is of frequent occurrence and that at best it can only be prevented by the most painstaking and continuous efforts." In his discussion of this subject at the meeting of the American Medical Association in June, 1912,[17] and at the meeting of the Pennsylvania State Medical Society, September 26, 1912, Robinson said that he now confines the use of suction drainage to only the most carefully selected cases.

It is an interesting fact that while the atmospheric pressure soon after the usual drainage opening is made is probably as great in the empyemic cavity as that exerted within the lung through the trachea, because the drainage opening is usually as large or larger in diameter than that of the trachea or larynx, in most cases the lung will expand later and obliterate the cavity. This is the more interesting when we take into consideration the fact that to the external pressure must be added the resistance of the normal elasticity of the lung and that of the inflammatory thickening of the inflamed pleura and adjacent lung tissue. In many cases this result will be accomplished in about four weeks without the employment of negative tension from suction drainage. Yet is is obvious that the lung can be expanded only by the atmospheric pressure coming through the trachea. The internal pressure in some way must gain on the external pressure. I have in several cases introduced my finger through the drainage opening at the time of the operation to find that I could not feel lung tissue or only a small portion of it. It was being held beyond the reach of the finger by the external atmospheric pressure exerted through the drainage opening. In 1 or 2 cases I have introduced the finger at intervals later to find that the surface of the lung could be felt to be approaching the opening. To my mind there is only one satisfactory explanation for it. The atmospheric pressure within the empyemic cavity must, in some way, be gradually diminished, so that the internal pressure can act to better advantage in expanding the lung. Otherwise the lung never could expand. In other words, the effect of the drainage opening usually employed is to provide more or less imperfectly, a negative tension within the empyemic cavity. We are all familiar with the sound made by the air which passes through the opening on inspiration during the after treatment even in the presence of a pus-soaked dressing. I observed in one of my cases that this sound ceased soon after the operation, perhaps in a few days, and in that case the cavity and sinus were closed in five weeks. I saw at the Philadelphia Hospital some years ago an empyema patient who had been operated on about two and a half years before. The drainage opening was more than an inch wide at that time. There was no sound in that case from the passage of air in or out, probably because the opening was so large. I could look through it into the cavity, and when I saw the case again a year later, as far as I could judge, no progress had been made toward the obliteration of the cavity and a cure. I have observed that the sinus is not long in closing after the sound made by the inrush of air on inspiration has ceased. Whether the sound ceases because the cavity has almost closed or the cavity closes more rapidly because the air has ceased to enter is uncertain, but it has seemed to me that if the entrance of air could be prevented the average case would be cured much sooner than it is. The small number of cases which I have had has prevented me from following up this idea as I would wish.

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[17] Jour. Amer. Med. Assoc., 1912, lix, 272.

In my opinion the size and position of the opening have an important bearing upon the results of the operation. Elsberg showed that the size of the opening was an important factor in connection with the effects of experimental pneumothorax in dogs. If the opening made in most operations remained afterward as large as when made, I think that in many cases the lung never would expand, because it would be practically as large as that of the trachea or larynx, so that the external atmospheric pressure would remain constantly as great or greater than the internal pressure. It seems to me that the external opening must become smaller than the internal, or the tracheal diameter, before the lung can expand. After the usual operation the falling in of the soft tissues contracts the opening, which is further filled by the walls of the drainage-tube, and the lumen of the tube and the space around it are more or less choked up continually by the escaping discharge and fragments of fibrin. The air already in the empyemic cavity is becoming absorbed, and if a smaller quantity passes in than is being absorbed the external pressure on the lung is being diminished, so that the internal pressure coming through the trachea remaining the same the lung slowly expands. The excision of several ribs may be advisable to get nearer to the bottom of the cavity, but not to provide freer drainage. Through-and-through drainage by two openings with a tube in each and one higher than the other, in my opinion, is worse. The higher opening will always be admitting air freely, because the pus will be escaping entirely by the lower, so that the upper will be a strong factor in preventing reëxpansion of the lung. The term free drainage in connection with empyema has not the same meaning as with abscesses in other parts of the body. In many abscesses an incision is made from one end of the abscess to the other, and lays the cavity wide open. The Estlander operation for chronic empyema provides such an opening, and the result shows what is to be expected from it. The free admission of atmospheric pressure permanently prevents reëxpansion of a large portion of the lung, which causes a marked sinking in of the side of the chest and a corresponding loss of lung function. The small opening usually employed in acute empyemas, if placed at the bottom of the cavity, would provide drainage quite free enough for the average case.

Robinson says that in the early stages, with the drainage opening at the bottom of the cavity, suction drainage will not be necessary. I am, particularly, trying to show that this will be true for most cases. In 2 cases I made the opening by resecting a small portion of the tenth and in 3 cases the eleventh rib near the spine. By dividing the intercostal tissues in the latter to the top of the twelfth rib practically the very bottom of the cavity was reached. I did this because of observations made on the formalin specimen, which shows that in that case at least there would have been no difficulty in making such an opening, and I found in my cases that it was about as easy and safe as resecting the sixth or seventh rib. A small puncture wound was made in about the seventh interspace or where the aspirating needle demonstrated pus. A somewhat rigid probe or a long grooved director, curved at the end, was then introduced through this opening and the end made to seek the lowest limit of the empyemic cavity, which usually corresponded to the bottom of the normal pleural cavity near the spine. The curve permitted the end of the instrument to be turned toward the surface where by careful palpation it could be felt by the finger outside over the corresponding interspace, usually the eleventh. A vertical incision was then made over this area, the eleventh rib exposed, and a small portion of it excised in the usual way. The probe or grooved director was then pushed outward through the pleura if it had not been already opened and a closed hemostatic forceps introduced at this point. The finger introduced through the opening thus made feels the twelfth rib below and the diaphragm at the bottom of the cavity. A drainage-tube is introduced after extending the opening by incision to the top of the rib below. A suture or two may be used to diminish the size of the opening slightly, but free drainage must be the first consideration. During the operation I have placed the patient in the prone position advised by Elsberg, and have found it satisfactory. In one case, as I was about to make the preliminary incision for the introduction of the probe, I happened to look at a clock and I concluded to time the operation. When the drainage-tube was in and the gauze dressing applied about four minutes, not more than five, had elapsed. With such an opening the empyema will be perfectly drained in almost any position the patient is likely to occupy. The shoulders will probably be higher at all times than the opening, the advantage increasing the more nearly the patient assumes the sitting position. The opening is at the bottom of the narrow space between the diaphragm and chest wall, so that all of the discharge will constantly gravitate toward it and will tend to prevent the entrance of air in so far as it continues to fill the space in and around the tube. Usually I have not been greatly concerned about fragments of fibrin choking the tube, because I have felt that the drainage was free enough around the tube, and through it around any fibrin that became lodged in it. At any rate it will give no more trouble than with a higher opening. When we consider that we can in a short time evacuate the accumulation of weeks through the ordinary aspirating needle, it becomes evident that not much space is necessary with such a low opening for the continuous evacuation of the discharge as it forms. Nor have I been concerned about the falling in of the drainage-tube, since it is usually directed upward as well as inward, and would have to travel against gravity to get inside; and if it did so, would be kept by gravity at the opening so that it could easily be fished out with a forceps

Agnew[18] applied the principle of dependent drainage in old empyemas with persistent sinuses, but maintained through-and-through drainage with a tube passed frm one opening to the other. Ashhurst[19] employed the same method of drainage from the beginning, and says: "I have seen a number of cases in which this plan has been systematically carried out with complete success." It seems reasonable to assume that the lower opening drained all the pus in Ashhurst's cases, since pus could escape from the upper opening (the patient usually occupies the semirecumbent position from the beginning and soon the upright) only if the cavity were full of pus, when the plan would hardly have been regarded as a complete success. The important point demonstrated by Ashhurst, in my opinion, is that an intercostal dependent opening only large enough apparently to pass the drainage-tube gave satisfactory drainage. But we have many surgeons who employ such an opening usually in the sixth or seventh interspace, especially in children. If the drainage is satisfactory through such an opening it ought to be better with the opening in the eleventh interspace. Only a scarcity of cases has prevented me from trying the low intercostal opening.

Some surgeons make efforts to remove fragments of fibrin at the time of operation. I have felt some concern about them because they were in a pus cavity and were probably made up of necrotic material. I had one experience, however, that modified this opinion. On introducing my finger through the drainage opening I found the pleural surfaces, parietal and diaphragmatic, covered uniformly as far as the finger could reach with a soft layer of fibrin about an inch in thickness, which could easily be swept off with the finger. It seemed obvious that the whole surface of the cavity was so covered and that it was all infected material. As it could not be removed I watched the after course of the case with much interest. The sinus closed and the patient was discharged in

[18] Agnew's Surgery, vol. i, pp. 344 and 345.

[19] Principles and Practice of Surgery, 1893, sixth edition, p. 410.

about five weeks. The layer of fibrin gave no trouble. It did not escape through the drainage opening unless it liquefied, which is unlikely. It is more probable that it remained and became organized into a thickened pleura. I did not discover such a deposit on the pleural surface in any other case. It suggests that in the pleural cavity we have the serous, serofibrinous, and fibrinous varieties of inflammation, as in other serous cavities, and that the thickened pleuræ found in some old cases at operation may be due to the organization of such deposits. Thomson and Miles[20] say: "Even in comparatively recent cases the pleura is thickened and covered with masses of flaky lymph, which may be an inch thick. In some cases of long standing this fibrinous exudate becomes organized and the pleura is greatly thickened."

In those troublesome cases in which the affected lung fails to expand after a prolonged period the last resort is a thoracoplasty, by the Estlander or Schede method, with or without removal of the thickened pleura covering the exposed part of the lung. Since the latter will not expand to obliterate the cavity the ribs overlying it are removed, permitting the weakened chest wall to fall in against the lung. The operation is frequently a severe one and the resulting deformity marked. The lung remains permanently collapsed in large measure, which with the sinking in of the chest wall produces a condition which is far from desirable. Robinson believes that these operations are too often employed in cases which are by no means beyond the possibility of reëxpansion. I believe that this is true. Ochsner[21] has made an important contribution to the treatment of these cases. In 14 cases he injected the cavity with Beck's bismuth paste, and all but 2, which were still under treatment, were cured. He has used it only in cases with sinuses, although, he says, it has been suggested to aspirate the pus in the empyema and to inject the paste into the cavity through the cannula. While the method appears to be decidedly better than thoracoplasty, it would hardly be advisable to employ it to the exclusion of the usual drainage method, which results in a cure in most cases, with almost if not complete reëxpansion of the lung. Any paste retained permanently must be at the expense of the non-expansion of a corresponding portion of the lung. The cases calling for the Ochsner method, or thoracoplasty, are usually chronic not in the sense that they have long existed without being opened, but are cases which were opened in the acute or subacute stages and became chronic while waiting for the lung to expand. It is likely that in the chronic cases the lung has expanded considerably since drainage was begun, and therefore will require a much smaller quantity of the paste than if injected at the time the pus was first evacuated.

(To be continued.)

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[20] Manual of Surgery, fourth edition, ii, 318.

[21] Annals of Surgery, 1909, i, 151.